

A. Descriptive Title Of The Invention:

A System For Remotely Adjusting Antennas

B. Cross Reference To Related Applications:

None

C. Statement Regarding Federally Sponsored R & D:

None

D. Reference To A "Microfiche Appendix":

None

E. Background Of The Invention

Field Of The Invention-

This invention describes a method, an apparatus, and a system for remotely adjusting by mechanical and electronic means the plumb-to-level and the compass heading of one or a plurality of communication antennas. The term plumb-to-level will be used throughout this description to represent absolute measurements with respect to true vertical. And, the term compass heading will be used throughout this description to represent absolute compass heading direction with respect to magnetic North.

A continuing problem for cellular telephone network planners is that of base station over or under coverage. That is, if the overlapping area between two cells is too large (i.e., over coverage), increased switching between the base station (handoff) occurs, which strains the system.

Likewise, if the overlapping area between two cells is too small (i.e., under coverage), gaps in service, or nodes, will occur. There may even be interference with other cellular networks using the same, or nearby, operating frequencies. To minimize the over and under coverage effects, a cost effective means to precisely position the antenna remains a continuing challenge.

This invention is not limited to antennas for cellular telephone network use only, but since this is the largest use, we will use this application in the following description. In general, radio frequency antennas are described as having a radiation pattern that is referred to as being a horizontal pattern and a vertical pattern, with the former being referenced along the horizon, as would a compass heading, and the latter being referenced from the vertical, as would plumb-to-level. Since cellular telephone traffic tends to concentrate in certain areas such as along a busy

highway, further performance optimization is accomplished by the ability to precisely position the antenna in a concentrated area.

The industry term for antenna position with respect to vertical angle is down-tilt. The term for antenna position with respect to horizontal angle is azimuth. Measurements of plumb-to-level (P-L) and compass heading (CH) are absolute and are referenced to the earth itself. Current methods for obtaining antenna settings such as down-tilt angle are measured with respect to a part of the tower itself. In the case of most radio antennas, this measurement is made with respect to the tower. However, these tower referenced measurements are subject to many induced errors caused by weather, ground shifting, disturbances, or human error that is inherent to the measurement process itself. Once the reference is flawed, then all the calibrations based upon the reference are in error.

There are several ways to adjust antenna down-tilt. One way is to adjust it electronically by using a phased-array antenna. Another way is by mechanical means, as in using a special down-tilt mounting bracket such as the EZ-Tiltz™ bracket. The mechanical method is the simplest method since it does not require sophisticated timing and electronic phasing circuits. A third way to adjust the antenna down-tilt is to use closed loop electro-mechanical control devices using encoders. Because of the reference issue described above, this method is also flawed, and care must be taken to use components that are compatible with electro-magnetic interference (EMI) sensitive communication electronics. The use of high frequency devices such as stepping motor drives is not recommended.

Unfortunately, antenna optimization that is accomplished by solely adjusting the down-tilt alone is limited. Improvements made by adjusting the down-tilt are only valid for one direction of the horizontal radiation pattern. Within the most critical range of down-tilt, the actual radiation coverage varies more according to the azimuth direction, but demonstrates that both the down-tilt and the azimuth adjustments are integral. A change results in a horizontal radiation half-power beam width which gets broader with increasing down-tilt angle rather than the desired narrower, more focused radiation beam. Since azimuth adjustments for antenna sectors (more than one antenna acting as one antenna) are difficult to adjust manually and are not available electronically, site planning personnel to date have not been able to accurately compensate for this effect. Site surveys provide P-L and CH information. Until now, only fixed, manual adjustments referenced to points on the tower are assumed to be accurate. This invention allows remote adjustments with absolute reference to survey data.

Cellular telephone network antenna systems found in the center of a "cell" usually consist of three sectors, positioned at 120° segments of the complete circle. Each sector usually consists of four antennas mounted on a common mounting bar. From this, it can be seen that a typical cellular telephone antenna site can have up to twelve antennas needing periodic adjustment. This is very labor intensive and expensive, and usually involves dangerous work high above the ground.

Description Of Related Art-

Singer et al., US Patent Number 6,239,744 B1, teaches a method for adjusting antenna down-tilt, but only from a broad-brush perspective. Singer fails to address the need for azimuth adjustments in order to optimize beam coverage of a specific location when consideration is given to traffic patterns, topography, and other networks. Further, the Singer patent is based on the use of built-in controllers for each antenna and antenna sector, remembering stored data, and utilizing local and remote displays. In Singer, sensing down-tilt position of the antenna is left to an angle decoder to determine the angle between the antenna and its mounting structure, but does not address the need to coincide site survey data and actual site conditions. Much attention is given to operational function in Singer, but little attention is given to indicate how the actual hardware, or any integrated system, may be created by following its teachings.

Zimmerman et al., US Patent Number 6,232,928, Bemier, US Patent Number 5,029,179, and Chavez, US Patent Number 5,963,179, all teach manually adjusted down-tilt or azimuth antenna brackets. No mention of a remote means of adjustment is made.

Fulop, US Patent Number 5,583,514, teaches a satellite antenna position optimization system that is fast, complicated and expensive, suitable for government satellite tracking, but not suitable for low cost commercial installations such as that required by small cellular antenna sites. Fulop teaches a method of using GPS data to establish antenna position, which is outside the scope of this invention.

Hill, US Patent Number 5,461,935, teaches a slip clutch linear actuator. This design is fatally flawed because over travel of the actuator could cause the mechanism to bind. With the spring loaded clutch, actuators are limited to a fixed amount of torque. If this torque limit is exceeded, the drive reaches a point of slippage, thereby causing an irreversible jamming condition due to limited torque settings of the slip clutch.

F. Summary Of The Invention

Objective And Advantages-

This invention addresses the disadvantages of current equipment and techniques, and provides the industry with an economical and efficient method of making remote P-L and CH adjustments of multi-antenna sectors typically found at cellular telephone networks.

5 In a typical cellular telephone network, base station performance deteriorates quickly due to over coverage and under coverage. It is the objective of this invention to provide a method and a hardware/software system to effectively optimize cellular network antennas by remotely adjusting antenna P-L and CH to eliminate over coverage and under coverage.

10 Antenna adjustments that are referenced to the support structure such as Singer are subject to many errors caused by weather, ground shifting, or disturbances due to the measurement process itself. Once the reference is flawed, then all the measurements based on that reference become corrupted. It is the objective of this invention to provide measurements and adjustments of down-tilt and azimuth that are made with respect to absolute geodetic measurements of P-L and CH.

15 Antenna site survey data is based on absolute P-L and CH information. To date, only fixed, manual adjustments of antenna down-tilt and azimuth can be made. It is the objective of this invention to provide a method for remote adjustments and measurements based on the same frame of reference.

20 Current methods of down-tilt adjustment of antennas by elaborate electronic means are limited and expensive. It is the objective of this invention to provide an electro-mechanical method of not only P-L adjustment, but also of CH adjustment by a simple, cost effective means that does not require sophisticated timing and electronic phasing circuits.

25 Due to the sensitive nature of communications circuits, extreme care must be taken to use components that are compatible with their electro-magnetic interference (EMI) sensitive circuits. The use of devices that emit high frequency interference such as stepping motor drives is not recommended. It is the objective of this invention to construct a remote antenna P-L and CH adjustment system using reliable, EMI free, motors and drives. Additionally, the invention of this application teaches a technique for preventing actuator damage by utilizing reversing relay limit switches.

30 Since convenient azimuth adjustments for antenna sectors (an array of more than one antenna acting as one antenna) are difficult to adjust manually, and until now are not available

electronically, site planning personnel have not been able to take this problem into consideration. It is the objective of this invention to provide a simple, low cost and remote method for making CH adjustments without having personnel climb to the top of towers or other similar structures.

5 Since up to twelve antennas may make up a typical cellular antenna site, with all needing periodic adjustment, manually making down-tilt and azimuth adjustments is very labor intensive and expensive, and usually involves dangerous work high above the ground. It is the objective of this invention to improve and simplify the process of remotely and quickly adjusting antenna P-L and CH, with economical, cost effective hardware, and without the need for personnel to climb any
10 towers or similar structures.

Systems that provide on site power and control of antenna adjustments may experience occasional tampering or interference by stray electrical transients. It is the objective of this invention to provide a secure, cost effective solution to the antenna adjustment requirement by providing a system that does not require on site power and computing or controlling capability. Additionally, one set of equipment may be used on many antenna sites by a single technician.

The details and many of the advantages provided by this invention will become clear and will be better understood by reviewing the following description and accompanying drawings, wherein:
20 the preferred embodiment offers a system for remotely adjusting the P-L and CH of one or a plurality of communication antennas.

G. Description Of The Drawings

Figure 1 is a typical antenna sector mounted atop a tower showing major components of the
25 invention

Figure 2 is an upper bracket.

Figure 2a is a lower bracket.

Figure 3 is an antenna sector with P-L and CH actuators

Figure 4 is an antenna sector with P-L and CH positioners

30 Figure 4a is an antenna sector with P-L and CH, (cut away showing P-L at its maximum)

Figure 5 is a linear actuator,

Figure 5a is a linear actuator (full half sectional view showing internal part detail)

Figure 5b is a linear actuator (cut away full sectional view showing more detail in the motor-drive screw area)

35 Figure 6 is a system block diagram

Figure 6a is a system block diagram, showing details of the interface module

Figure 7 is a software block diagram

H. Detailed Description

Fig. 1, shows a communications antenna system having, typically, four duplex transmitting and receiving cellular antennas mounted as a sector atop a suitable structure such as, for example, a tower. Furthermore, each cellular system tower may have up to three such sectors, each sector covering a segment that is usually 1/3 of a circle (120°). Referring to Fig. 1, a system for remotely adjusting the P-L and CH of one or a plurality of communication antennas, the subject of this invention is shown comprising: an antenna sector optimizer 10, mounted atop a tower, one or more weatherproof field interconnection boxes 60 and 64, an interconnection cable 62 running between the field boxes, one or more DC power sources 68 and 70, and a laptop computer 66. Although four antennas are shown to represent a sector in Fig. 1, this is not intended to be a limitation in scope, as one or a plurality of antennas may comprise a sector as defined by this invention. It is within the scope of contemplation of the inventor that the tower might be a building, a wall, or other appropriate manmade or natural structure. Furthermore, there may be one or a plurality of field boxes used, even though Fig. 1 shows two boxes being used. The invention will work equally as well with one or many field boxes being used. Also, Fig. 1 identifies a wire cable as the interconnection cable 62, however, future technology might allow this cable to be fiber optic or other interconnection means. Although Fig. 1 shows two DC power sources, it is within the scope of contemplation that any suitable power source such as, but not limited to, AC line power, "green" power, generator power, or similar power sources, could power this system. And finally, even though Fig. 1 depicts a laptop computer, it is highly likely that a remote mainframe or desktop computer may also be utilized to practice this invention.

Fig. 2 depicts the upper down-tilt bracket 18. Fig. 2a depicts the lower down-tilt bracket 20.

Fig. 3 is a cutaway view of the antenna sector optimizer 10, showing two antennas making up the sector. Although Fig. 3 shows only two antennas making up the sector, it is within the scope of contemplation that any number of antennas may be used to make up the sector. The antennas 12 are firmly attached to the tower by way of a mounting bar 40, normally one of three positioned to form a triangle at the top of the antenna tower. These bars are welded to the tower thereby providing a fixed, rigid attachment. Each antenna 12 of the sector is attached to an individual electromechanical linear actuator hereinafter referred to as the P-L actuator 14. The preferred embodiment of this invention utilizes the EZ Actuator™ linear actuator, however, other suitable linear actuators may be used to practice this invention. The antenna 12 of the sector is attached to the P-L actuator 14 by an upper down-tilt bracket 18 and a lower down-tilt bracket 20 (Fig. 2

and Fig. 2a). Although the preferred embodiment of this invention utilizes the EZ Tiltz™ brackets, any other suitably configured tilt brackets may be used to practice this invention. Another key bracket is the actuator bracket 28. The P-L actuator 14 is attached to the mounting bar 40 by an actuator bracket 28 and to the antenna 12 using the upper down-tilt bracket 18 and the lower down-tilt bracket 20. The assembly of these components provides the tilt adjustment of the antenna sector optimizer 10.

Referring again to Fig. 3, in order to provide CH adjustment to the antenna 12, the antenna sector optimizer 10 is provided with an additional electromechanical linear actuator hereinafter referred to as the CH actuator 16. The preferred embodiment of this invention utilizes the EZ Actuator™ linear actuator, however, other suitable actuators, linear or otherwise, may be used to practice this invention. The CH actuator 16 is attached to the mounting bar 40 using a pair of U-bolt or universal fasteners 26 (only one is shown in the cutaway view). Each individual P-L actuator 14 is attached to a CH tie bar 30 through a pair of pitman arms 24. The CH tie bar 30 is attached to the top of the CH actuator 16 with an additional upper down-tilt bracket 18. The assembly of these components provides the CH adjustment of the antenna sector optimizer 10.

Fig. 4 depicts an end view of the antenna sector optimizer 10 with the P-L actuator 14 in its minimum position and the antenna 12 in its least tilted position. A cutaway view, Fig. 4a, shows the same detail, but with the P-L actuator 14 in its extended position, and the antenna 12 in its full tilt position. Fig. 4 shows that the lower down-tilt bracket 20 has one hinged part, and is clamped to the lower half of the P-L actuator 14 at a fixed position. Further, Fig. 4 shows the lower down-tilt bracket 20 is bolted to the bottom area of the antenna 12. It shows that the upper down-tilt bracket 18 is hinged in two places, and is attached at the top of the P-L actuator 14 and to the top area of the antenna 12. This double hinge action makes the top of the antenna 12 tilt forward as the P-L actuator 14 is extending, and conversely, it makes the top of the antenna 12 tilt backward when it is contracting.

Continuing to refer to Fig. 4, the actuator bracket 28 is a casting or weldment forming a vertical surface having a tangentially positioned vertical tube on its back side. The P-L actuator 14 is inserted into the tube. Heavy grease is packed between the actuator and the inside of the tube as a means of dampening the rotational motion of the P-L actuator 14 caused by wind loading and other vibrational forces exerted on the antenna. The P-L actuator 14 is held vertically in place by a pair of pitman arms 24, one located above the tube and one located below the tube. The pitman arms 24 limit the up and down movement of the P-L actuator 14, and allow it to rotate with respect to the actuator bracket 28. The pitman arms 24 are in turn attached to a CH tie bar

30 using pitman arm attachment pins 32. Movement of the CH tie bar 30 causes all pitman arms to move such that the P-L actuators 14 attached to each and every antenna 12 in the sector rotate (change CH) together, thereby causing a uniform redirection of the antenna sector CH.

5 The CH tie bar 30 is attached to the CH actuator 16 by the upper tilt bracket 18. This bracket has two hinges and is the same as the upper tilt bracket 18 used to attach the antenna 12 to the P-L actuator 14. As the CH actuator 16 extends from its minimum length to its maximum length, the P-L actuators 14, and thereby, the antennas 12 rotate through their full sweep of CH rotation.

10 Also shown in Fig. 4, are the CH detector 52 and the P-L detector 50.

Antenna Sector P-L/CH Actuator

15 Fig. 5 shows a side view of an actuator 100 used in this invention for both the P-L actuator 14 and the CH actuator 16. Both of these actuators (14 and 16) are motor driven linear actuators. In this invention, the EZ Actuator™ linear actuator is used for the P-L actuator 14 and the CH actuator 16. It is within the scope of contemplation of this invention that other suitable linear actuators may be used.

20 The actuator 100 comprises three main parts, the actuator crown 102, the dust shield 108, and the main body extrusion 122. During normal operation, power being applied to the internal motor, (as described below) causes the linear actuator to increase or decrease its length, and the distance between the actuator crown 102 and the main body extrusion 122 changes accordingly.

25 Details of the actuator 100 may be seen by referring to Fig. 5a. For greater detail, refer to the cutaway view of the central section of the actuator, Fig. 5b. The actuator crown 102 seats inside the top of the dust shield 108 and is pinned in place. The dust seal bearing 114 snaps in place in the bottom of the dust shield 108 with 3 interlocking rings set into matching grooves on the inside of the dust shield 108. The linear ram 116 fits into a square socket on the bottom of the actuator crown 102 and is held in place by the same pins that hold the actuator crown 102 to the dust shield 108. The dust seal bearing 114 slip fits over the outer diameter of the main body extrusion 122 allowing movement up and down without allowing exterior particle contaminants to enter past the seal. The spines 120 fit into a channel inside the main body extrusion 122. The motor mount 126 holds the motor 180 and the electronics control board (not shown) in the bottom of the main body extrusion 122. Appropriate slots in the surface of the motor mount 126 allow the placement of the spines 120 between the exterior of the motor mount 126 and the interior of the main body extrusion 122. The drive coupler 176 is attached by threads and a counter screw to the drive end

of the motor **180**. The drive coupler **176** slip fits into the bottom of the drive shaft **170** and is held in place by the roll pin **174**. The anti-rotate lock cap **178** press fits around the bottom end of the drive shaft **170** and is secured in place by the same roll pin **174** that allows the drive coupler **176** to turn the drive shaft **170**. The spring loaded drive socket **164** is press fit into the top end of the drive shaft **170**. The geometry of the drive coupler **176** creates a linear movement in the drive shaft **170** and communicates with the anti-rotate lock cap **178** just before rotation begins. Lock teeth geometry at the interface of the anti-rotate lock cap **178** and the motor mount **126** prevent rotation of the mechanism when the motor **180** is not active and turning in either direction. This action defines the actuator's mechanical braking function. Four bolts hold the bottom of the spines **120** and the motor mount **126** to the main body extrusion **122**.

The drive shaft bearing spacer **172** is seated in the spines **120** and centers the drive shaft **170**. The drive nut **162** is screwed halfway onto the bottom end of the all-thread **118**. The lock bolt **165** is screwed into the bottom portion of the drive nut **162** against the face of the all-thread **118**, this locks the drive nut **162** and all-thread **118** together. The bearing block with thrust bearings **158** is located on the all-thread **118** between the drive nut **162** and the bearing position lock nuts **156**. The linear ram nut **152** is positioned an appropriate distance away from the top of the bearing position lock nuts **156** on the all-thread **118**. The linear ram nut **152** is pinned to the inside bottom of the linear ram **116**. The two ram bearing guides **110** are appropriately positioned to prevent the linear ram **116** from flexing out of alignment or rotating in its housing during operation. The all-thread end lock nuts **106** are screwed onto the top end of the all-thread **118**.

The limit switch rod position lock nuts **154** are placed on the limit switch rod **150** at the top and at the bottom so that when the linear ram nut **152** moves and contacts one of the limit switch rod position lock nuts **154**, it moves the limit switch rod **150** up or down accordingly. The limit switch rod **150** then moves the limit switch trigger block **168** up or down accordingly. The limit switch trigger block **168** then activates the limit switch **166** sending a signal to the field box(es) that the actuator (P-L actuator **14** or CH actuator **16**) are at the end of their designed travel limit. A reversing relay immediately switches polarity to the drive motor. That relay is actuated by the limit switch. A capacitor is then positioned across the reversing relay coil. This capacitor provides a specific amount of time for the motor to reverse thus giving the trigger block sufficient time to clear the limit switch and eliminate bounce-back. Simultaneously, when the reversing switch is actuated, it closes a set of contacts that alerts the computer that the end of travel has been reached.

In an alternative embodiment of this invention to allow a cost effective solution to the problem of sweeping one or a plurality of antennas from one sector to another sector of the same cell site array, and then compliment the new P-L and CH settings of their new sector. This cost effective solution allows the system to balance sector traffic loads and access underutilized capacity in sectors that have capacity to spare.

Field Connection Interface

Fig. 6 is a signal block diagram for the system for remotely adjusting the P-L and CH of one or a plurality of communication antennas showing the antenna sector optimizer, the field box(es), the laptop computer, and the DC power sources.

Referring to Fig. 6, the P-L portion comprises a P-L actuator **14** and a P-L detector **50**. The CH portion comprises a CH actuator **16** and a CH detector **52**. Both actuators, in the preferred embodiment, are powered by standard DC motors. When DC power is applied with a positive polarity to the actuator, the actuator increases in length. When DC power is applied with a negative polarity to the actuator, the actuator decreases in length. When the motors are not being actuated, a shorting resistor is placed across the terminals of the motor thereby creating a method for dynamic braking.

There is one P-L detector **50** and one P-L actuator **14** for each antenna in the sector. A sector typically has from one to four antennas. The P-L detector **50** detects the antenna P-L with respect to true vertical or horizontal. Unlike sensors that measure antenna angle with respect to a tower member, this novel invention automatically eliminates errors caused by unavoidable changes in the base reference by using a P-L detector that incorporates an encapsulated electrolyte solution. In the preferred embodiment, this is a dual axis DX-045 detector sold by AOSI of Linden, NJ.

Each antenna sector has a CH actuator **16** to adjust the CH or direction of the entire antenna sector. Each sector also has a CH detector **52** for determining the actual CH of the sector. There is one CH actuator **16** and one CH detector **52** for each sector. A tower or site, may have multiple sectors. In the preferred embodiment, the CH detector used is a model TCM2-20 sold by PNI Corporation of Santa Rosa, CA.

So that each antenna and each sector may be adjusted independently, each actuator (both P-L actuators and CH actuators) has a separate activation relay for the detector and separate activation relay for the actuator motor. This allows all antennas to be independently monitored

and adjusted using one set of field boxes and one laptop computer by simply addressing each antenna P-L or each sector CH. An activation relay for the P-L actuator 14 is housed in the P-L actuator 14. An activation relay for the CH actuator 16 is housed in the CH actuator 16. An activation relay for the P-L detector 50 is housed inside the P-L actuator 14. An activation relay for the CH detector 52 is housed inside the upper field box 60. In the preferred embodiment, wires from the P-L detectors 50 are connected to their respective actuators. Wires from the CH detectors 52 are connected to the upper field box 60. Wires from all actuators are connected to the upper field box 60.

The field box 60 contains electronic circuitry to provide the signal conditioning and the logic selection for the specific antenna and/or sector being addressed. The P-L detector 50 is connected to the electronic P-L circuit board 74 wherein the amount of deviation from true P-L (that is, with respect to the earth's gravity) is converted into a 0-5VDC signal. This signal, in turn, is converted to an 8 bit digital signal by the analog to digital converter 76 that is compatible with the laptop computer 66.

The CH detector 52 is connected to the electronic compass circuit board 84 wherein the amount of deviation from true North (that is, with respect to the earth's magnetic field) is converted into a 0-5VDC signal. This signal, in turn, is converted to an 8 bit digital signal by the analog to digital converter 86, which is compatible with the laptop computer 66.

In Fig. 6a, the interface module 90 relays the logical addressing and data reading function in response to commands given by the laptop computer 66. Eight bit binary data from each detector is converted into two, 4 bit binary bytes by each of two octal bus line drivers 92 and 94. The byte is selected by the laptop computer. Further, a third octal bus line driver 96 selects which of the two data sources the laptop computer is reading at any one time. Here, the laptop computer selects which detector is being read. This conversion allows the data from the two detectors to be transferred to the laptop computer over four wires, rather than the sixteen wires that would normally be required. Also, by addressing each antenna and each sector separately, the number of sets of wires needed to read all the data is substantially reduced from a maximum of 19 sets to just the 1 set. The 4 to 16 Line Decoder/Demultiplexer 98 selects the detector relay and the actuator relay that is requested by the laptop computer. This is not meant to be a limitation, but rather it is within the scope of contemplation of this invention that the 4 to 16 Line Decoder/Demultiplexer 98 could be potentially expanded to include additional such devices.

Referring again to Fig. 6, to insulate the electronic circuits in the field boxes to transients and other electrical disturbances that may cause damage or malfunction, each box is provided with optical isolation circuits for each communication line. In the preferred embodiment, there are two boxes requiring two optoisolators 91 and 93.

In the preferred embodiment, there are two identical sources of power, 68 and 70, both of which are standard rechargeable 18 VDC battery packs. DC power 1 68 is connected to a voltage regulator circuit 72 thereby creating regulated voltages Vcc and 9_Vdc. These regulated voltages are needed to power the logic contained in the field boxes 60 and 64, and the electronic compass 84 as part of the antenna sector optimizer 10, and the electronic P-L board 74.

In response to a command from the laptop computer, a forward/reversing relay 88 reverses the polarity of the 18VDC power circuit used to drive the P-L actuator 14 and the CH actuator 16 when it is desired to increase or decrease the length of either actuator.

In the preferred embodiment, power, control and computing functions are brought to and applied to the system by the technician while making adjustments. This is to prevent tampering or sporadic responses to outside disturbances, as would be possible in a system with on site power and control capability. Also, another benefit of portable power and user furnished computing equipment, allows the same equipment to be used on many antenna sites, thereby providing an additional cost effective solution to the optimization process.

Laptop Computer and Application Software

The key to the performance of this system for remotely adjusting the P-L and CH of one or a plurality of communication antennas is in the antenna optimization application software. In the preferred embodiment, the antenna optimization application software is run on a laptop computer. The computer having the antenna optimization application software allows the operator to remotely adjust the P-L of any antenna or the CH of any antenna sector merely by connecting the laptop computer to the optimizer system at the lower field box. This eliminates the need for the technician to climb the antenna tower. By connecting the DC power source along with the laptop computer, the technician may perform the necessary optimization adjustments without the need for any other additional outside resources.

The system for remotely adjusting the P-L and CH of one or a plurality of communication antennas is not limited to use by a locally connected laptop computer. An alternative embodiment might utilize an on site desktop computer. Another alternative embodiment might

utilize a mainframe computer. It is contemplated that computers located at other sites, connected by wire or modem, may also be used.

The antenna optimization application software can run on almost any personal computer (PC) with minimal specifications. The PC may be any one of the standard microprocessor types commonly found in use. Since large amounts of processing power is not necessary, any suitable 8 bit or greater microprocessor, such as for example an Intel 86286 or greater, with a processing speed of 20 MHz. or greater, may be used. The PC should have at least one standard parallel port, and a standard display. It need not have sound reproduction capability.

The application software for remotely adjusting the P-L and CH of one or a plurality of communication antennas operates under any version of MS Windows or other standard operating system that employs a similar architecture.

A block diagram of the application software is provided in Fig. 7a through Fig. 7o. The application software **200** comprises an initialization routine **202**, followed by two operator prompts, connect to parallel port **204** and connect power source **206**, and a routine calibrating the electronic P-L and CH **208**. If wind is present **210**, the program branches to prolonged sampling **211**. If not, the program maintains its normal sampling and advances directly to the additional prompts. The program prompts the user to input the number of antennas in the array **212** (n), and input the number of antennas per sector **214** (n'). Then the program reads the P-L value from each antenna and the CH value from each sector, and stores the values in a memory array **216**.

The user is asked to select one of eight options **218**. If option 1 (Display All Current Antenna P-L) was selected **220**, the program branches to the option 1 routine. Option 1 proceeds to set the antenna address to 1 **224**, read a new P-L value from the selected antenna **226**, store it in the memory array and increment the antenna number **228**, and pause 0.5 seconds to stabilize the system **230**. If the antenna number is $n+1$ **232**, all the P-L values from the array are displayed **234**, followed by a return to the selection screen **236**. If the antenna number is not $n+1$ **232**, then the program returns to read a new P-L value **226**.

If the one of eight options **218** chosen was not option 1, then the program will test to see if option 2 was selected **238**. If option 2 (Adjust Individual Antenna P-L) was selected, then the program branches to the option 2 routine. Option 2 proceeds to initiate the antenna adjustment routine where the user is prompted for the antenna address to be adjusted **242**, actuates the address of the selected antenna **244**, read a new P-L value **246**, displays the new P-L value, prompts the

user for a desired P-L value **248**, and determines if the new P-L value is smaller than the desired P-L value **250**. If the new P-L value is smaller, the program branches to actuate the P-L actuator motor in a reverse direction **252** before proceeding to the next operation. Or, if the new P-L value is not smaller, the program continues to actuate the P-L actuator motor in a forward direction **254**.

5 The program reads a new P-L value **256** and checks to see if the new P-L value is within 0.1 degree of the desired P-L value **258**. If the answer is no, the program returns to get another new P-L value **256**. If the answer is yes, the program stops the P-L actuator motor **260**, pauses 1 second **262**, and gets a new P-L value **264**. If the new P-L value is not within 0.1 degree of the desired P-L value, the program returns to check if the new P-L value is smaller than the desired P-L value **250**. If the new P-L value is within 0.1 degree of the desired P-L value, the program continues and displays the new P-L value **270** and returns to the selection screen **271**.

15 If the one of eight options **218** chosen was neither option 1 nor option 2, then the program will test to see if option 3 was selected **272**. If option 3 (Adjust Complete Sector P-L) was selected, then the program branches to the option 3 routine. Option 3 proceeds to prompt the user for the sector number **276**, prompt the user for a desired P-L value **278**, selects the address of the first antenna in the sector and gets the new P-L value **280**. The program tests to see if the new P-L value is smaller than the desired P-L value **282**. If the new P-L value is smaller than the desired P-L value, the program branches to actuate the P-L actuator motor in a reverse direction **284** before proceeding to the next operation. Or, if the new P-L value is not smaller than the desired P-L value, the program continues to actuate the P-L actuator motor in a forward direction **286**. The program reads a new P-L value **288** and checks to see if the new P-L value is within 0.1 degree of the desired P-L value **290**. If the answer is no, the program returns to get another new P-L value **288**. If the answer is yes, the program stops the P-L actuator motor **292**, pauses 1 second **294**, and reads a new P-L value **296**. If the new P-L value is not within 0.1 degree of the desired P-L value, the program returns to check if the new P-L value is smaller than the desired P-L value **282**. If the new P-L value is within 0.1 degree **298**, the program increments the antenna address **300** and pauses for one second **302**. If the antenna number is not $n'+1$ **304**, the program returns to check if the new P-L value is smaller than the desired P-L value **282**. If the antenna number is $n'+1$, the program continues and displays the new P-L value **306** and returns to the selection screen **308**.

35 If the one of eight options **218** chosen was not any of the options 1 through 3, then the program will test to see if option 4 was selected **310**. If option 4 (Adjust Complete Array P-L) was selected, then the program branches to the option 4 routine. Option 4 proceeds to prompt the user for a desired P-L value **314**, set the antenna address to 1 **315**, activate the antenna address

for the first antenna 316, and get a new P-L value 318. The program tests to see if the new P-L value is smaller than the desired P-L value 320. If the new P-L value is smaller than the desired P-L value, the program branches to actuate the P-L actuator motor in a reverse direction 324 before proceeding to the next operation. Or, if the new P-L value is not smaller than the desired P-L value, the program continues to actuate the P-L actuator motor in a forward direction 322. The program reads a new P-L value 326 and checks to see if the new P-L value is within 0.1 degree of the desired P-L value 328. If the answer is no, the program returns to get another new P-L value 326. If the answer is yes, the program stops the P-L actuator motor 330, pauses 1 second 332, and reads a new P-L value 334. The program then checks to see if the new P-L value is within 0.1 degree of the desired P-L value 336. If the new P-L value is not within 0.1 degree of the desired P-L value, the program returns to read a new P-L value 318. If the new P-L value is within 0.1 degree of the desired P-L value, the program increments the antenna address 338 and checks to see if the antenna number is $n+1$ 340. If the antenna number is not $n+1$, the program returns to activate the antenna address 316. If the antenna number is $n+1$, the program returns to the selection screen 342.

If the one of eight options 218 chosen was not any of the options 1 through 4, then the program will test to see if option 5 was selected 344. If option 5 (Exit Program) was selected, then the program branches to the option 5 routine. Option 5 proceeds to display the exit statement 346 and stop the program 348.

If the one of eight options 218 chosen was not any of the options 1 through 5, then the program will test to see if option 6 was selected 350. If option 6 (reserved for future program- Initiate Auto EZ Optimizer) was selected, then the program branches to the option 6 routine. Option 6 is reserved for a future routine 352 whereby the antennas can be monitored and adjusted by way of the internet, intranet, or other modem based communication means.

If the one of eight options 218 chosen was not any of the options 1 through 6, then the program will test to see if option 7 was selected 354. If option 7 (reserved for future program- Adjust Electronic Tilt) was selected, then the program branches to the option 7 routine. Option 7 is reserved for a future routine 356 that will allow the operator to adjust an antenna that has an internal electronic tilt system.

If the one of eight options 218 chosen was not any of the options 1 through 7, then the program will test to see if option 8 was selected 358. If option 8 (Adjust Sector CH) was selected, then the program branches to the option 8 routine. Option 8 proceeds to prompt the user to select the

sector **364**, actuate the address of the selected sector **366**, read a new CH from the electronic compass, and display the CH **368**. The routine then prompts the user for a desired CH **370**, and tests to see if the new CH is smaller than the desired CH **372**. If the new CH is smaller than the desired CH, the program branches to actuate the CH actuator motor in a reverse direction **376**
5 before proceeding to the next operation. Or, if the new CH is not smaller than the desired CH, the program continues to actuate the CH actuator motor in a forward direction **374**. The program reads a new CH **378** and checks to see if the new CH is within 0.1 degree of the desired CH **380**. If the answer is no, the program returns to get another new CH **378**. If the answer is yes, the routine stops **382**. If option 8 was not selected **358**, the program proceeds to try again by
10 prompting the user for a new option **362**.